Development of ^{211}At production at UC Davis

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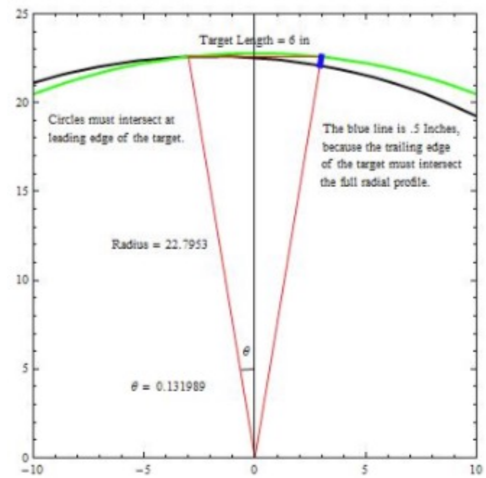
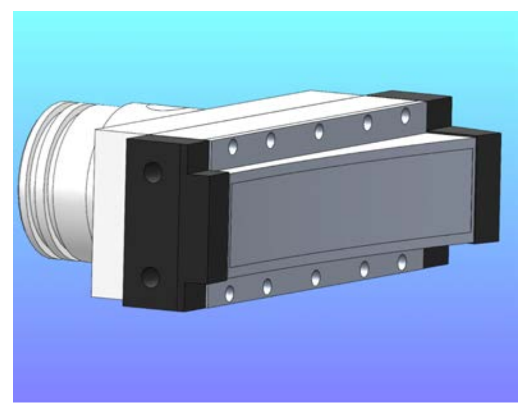




Crocker Lab Astatine Team

Prof. Eric Prebys: PI

Prof. Daniel Cebra: Co-PI

Kathleen Stewart: grad student, ^{211}At recovery processing

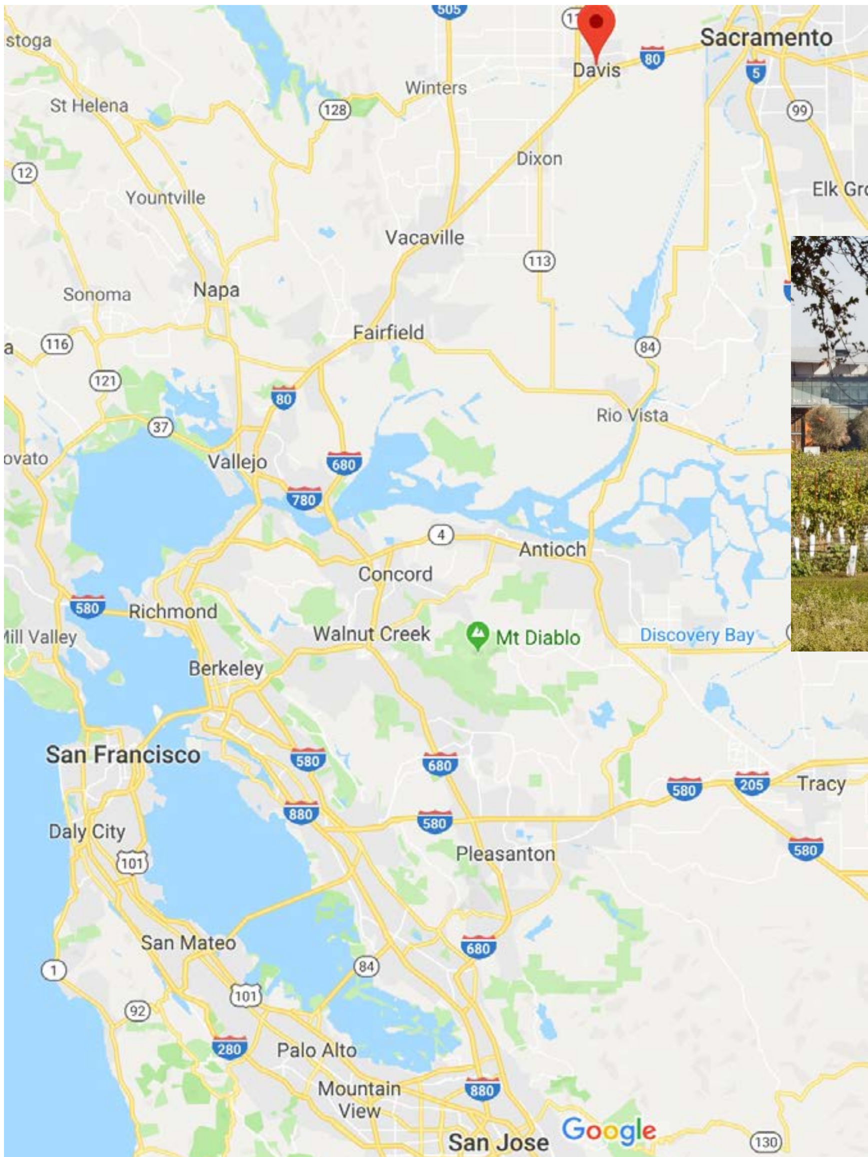
Michael Backfish: Beam studies, cyclotron operations

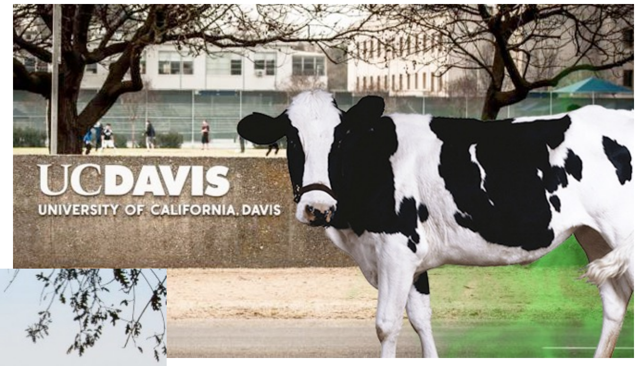
Brian Devine: Target Design and Fabrication

Lena Korkeila: grad student, cyclotron modeling and operations

Orientation

- CNL is “centrally isolated” at UC Davis, near Sacramento



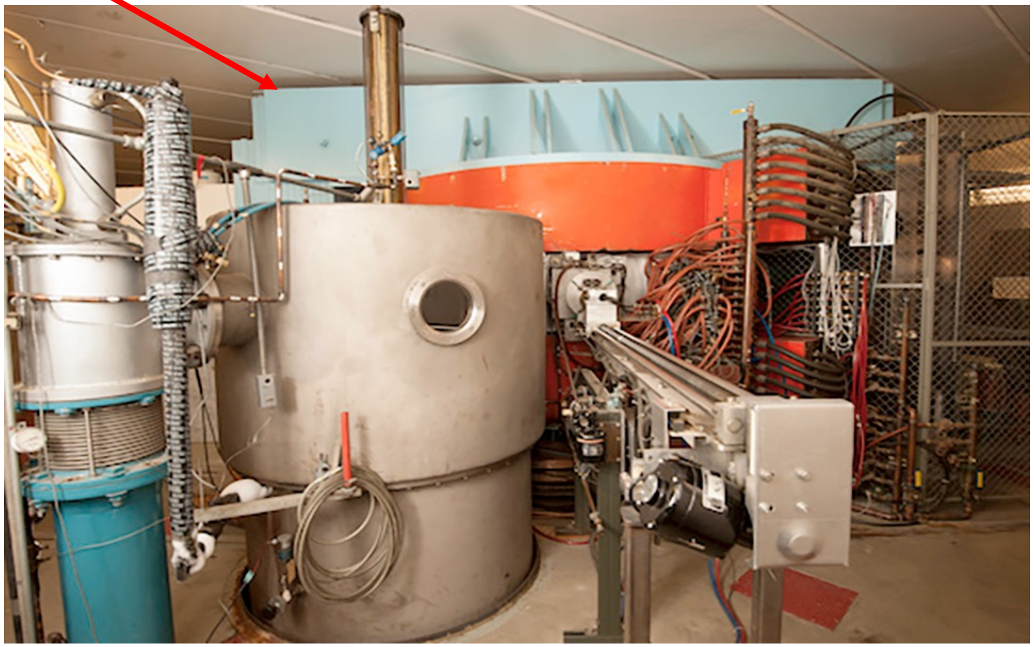


Crocker Nuclear Laboratory

Crocker Nuclear Laboratory Cyclotron

- The Cyclotron at Crocker Nuclear Laboratory can accelerate protons, deuterons, or alpha particles to variable energies, up to 67 MeV for protons.

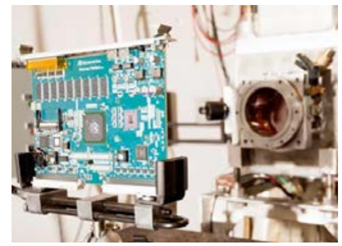
Yoke and central pole pieces from Lawrence's 60" cyclotron at Berkeley (where ^{211}At was discovered!)



Upgraded and commissioned in 1966, based on the design of the Oak Ridge Isochronous Cyclotron (ORIC)

Motivation for Developing ^{211}At at Crocker Nuclear Lab

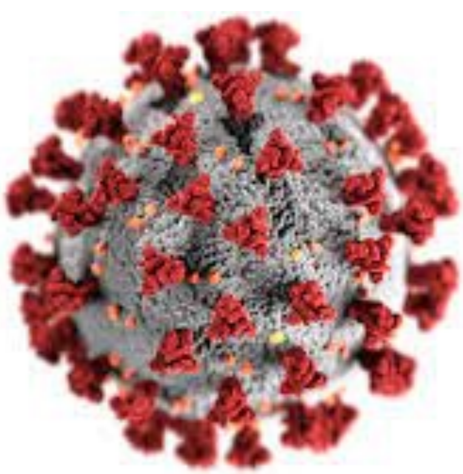
- For several decades, Crocker Nuclear Lab has been self-supporting, through charging to provide beam to…
  - The UCSF Radiative Oncology Team one week/month to treat uveal cancer (cancer behind the retina)



  - Study radiation effects on materials and electronics for a diverse group of users, primarily in the aerospace industry.
- A few years ago, the university determined that simply providing a service for a fee was not really in their mission, so
  - The cyclotron was separated from the “Air Quality Research Center”, to which it had been attached.
  - I was brought in four years ago with a mandate to increase the scientific output of the facility.
- We determined that the production of ^{211}At provided an opportunity to expand the lab’s role, in that
  - It’s well-matched to the capabilities of the cyclotron and the lab
    - We’ll use the reaction ^{209}Bi(α,2n)^{211}At
  - There’s a community of interested users in the area, with no nearby source.

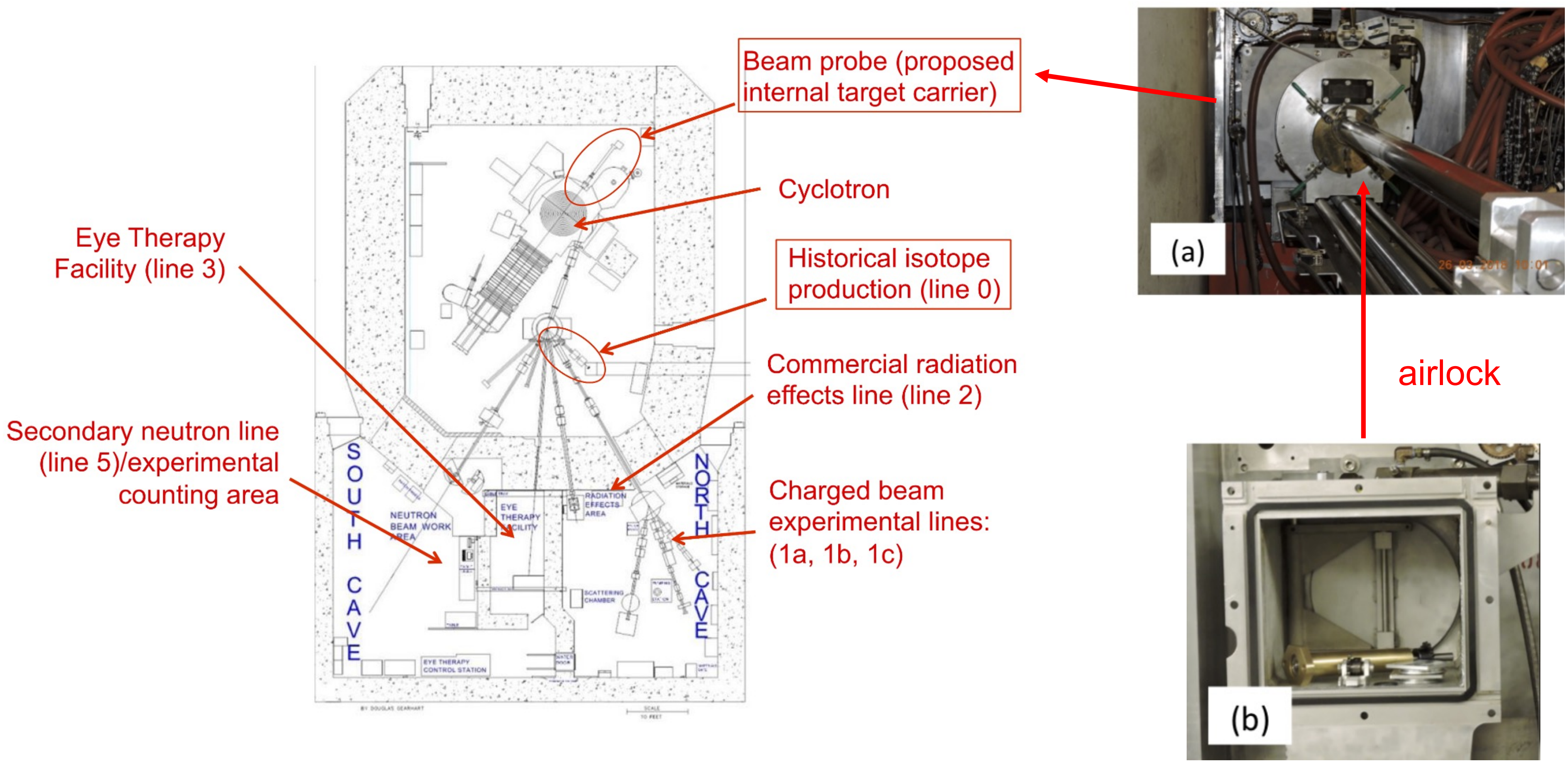
Challenges…

- Anticipated challenges:
  - CNL has not produced any isotopes since 1994
    - Prior to this project, the filament supply had been replaced by one that did not provide the high bias voltage needed to produced high currents.
  - Our extraction efficiency for α particles is typically very low (<50%)
    - Decision to use internal target (like Duke University)
  - There has never been a proper computer model of the cyclotron
    - It was built as a copy of the Oak Ridge Isochronous Cyclotron, and once they got it working, they really never worried about it again.
- Unforeseen challenge:



Proposed Technique

- Our cyclotron does not allow for a separate beam probe and target, like the Duke University cyclotron, so our plan is to develop a combination target/probe using the existing probe line.

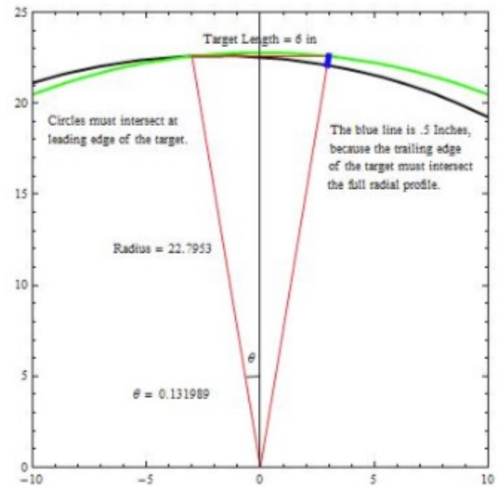


Scope of Project

- Funded period: 9/1/19-8/31/21
  - Original scope (with requested budget)
    - Design and fabricate target
    - Outfit recovery lab at CNL
      - Investigate both wet and dry chemistry
    - 100 μA of a-beam on target at 29 MeV
    - Recover 60 mCi of ^{211}At in solution in an 8 hour shift
      - 1 hour setup
      - 5 hour exposure
      - 2 hour processing
  - Revised scope (with awarded budget):
    - Use Prof. Cebra's lab in the Physics building
    - Investigate only we chemistry initially
    - Aim to recover ^{211}At on the order of a few mCi to establish capability
  - Status: *almost* there

Key Progress and Milestones

- A proper model of the cyclotron, based on OPAL-CYCL
  - Used to design target



- New filament supply allowed us to increase a current from <1 μA to ~30 μA.
  - Enough for our goals!

Progress and Milestones (cont'd)

- Internal α profile measurement in cyclotron

Roughly 1cm x 1cm. Wider than expected, but that's good news, in terms of distributing the heat load!

(We still don't fully understand this)

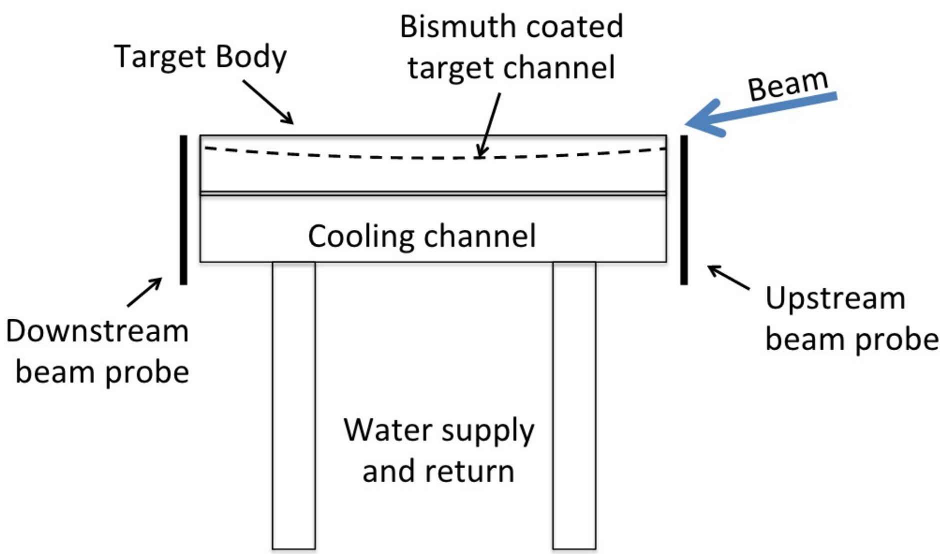
- Outfitting of Professor Cebra's Lab

Effects of Covid-19

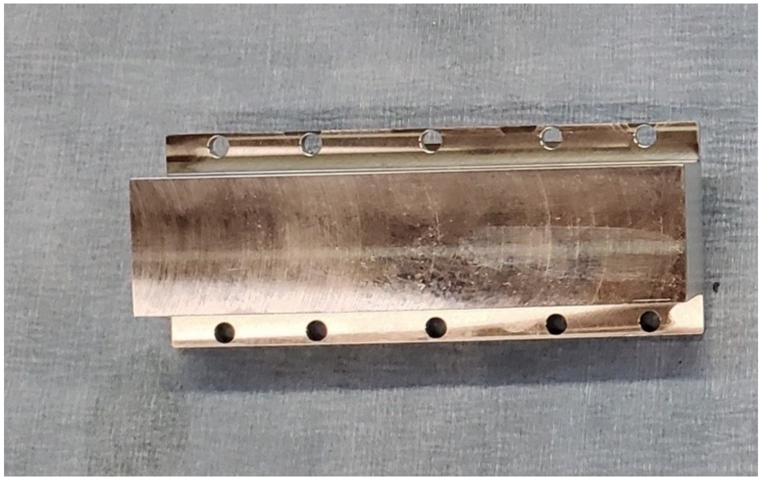
- On March 15th, 2020, in response to the rapidly grown pandemic, we issued a shelter in place order and ceased routine operations.
  - Only Eye Therapy continued one week/month, with extreme precautions in place.
  - Except for simulation work, progress on ^{211}At project effectively stopped.
- On May 12th, 2020, we were given “Phase 1.x” approval to operate.
  - Strict social distancing protocols
  - People were still encouraged to work from home
  - Priority given to paying customers
  - ^{211}At program creeped back to life, but was still severely impacted.
- Starting on June 1, 2020, activities gradually ramped back up to pre-pandemic levels, but there’s no question time had been lost.

Target/Probe Design

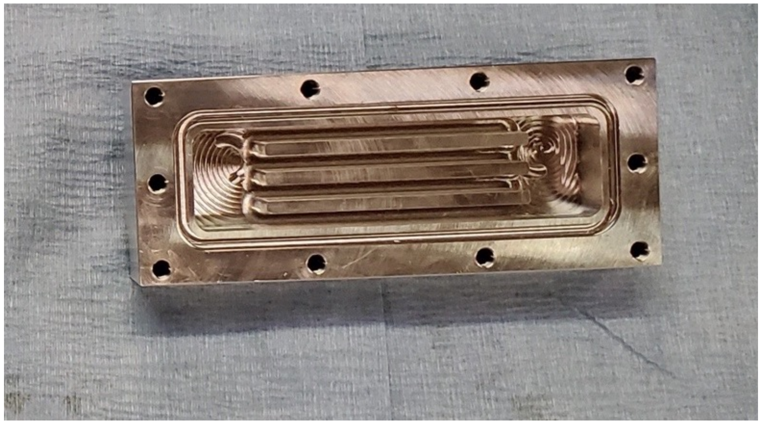
Conceptual Design



First Prototype



Read View



Also perfected ^{209}Bi coating

- Painted on with steel wool brush

Target Beam Tests

- We did a series of beam tests in early March, in which we monitored the current on the leading probe, target body, and trailing probe.
- Our data showed that most of the beam was falling on the leading probe, with very little current on the body or trailing edge.
- We modified the trailing probe to extend further and determined our target angle was off by about ¼” from leading to trailing edge.
  - This was tracked down to an error in our modeling.
- A new target was fabricated, and subsequent beam tests showed we should be able to get at least half of the beam on the target
  - Good enough to meet our initial goals.

Status and Plans

- We had planned to do our first production exposure a week ago, but a pump failure brought the machine down for two weeks
  - Did I mention this cyclotron is old?
- We are ready to go with production exposures
  - In the first exposure, we will assay the target with an HPGe detector to determine the amount of ^{211}At we have produced.
  - In the next exposure, we will run for long enough to produce ~1 mCi of ^{211}At and recover it.
- Time scale? Next few weeks.
  - We're requesting a no-cost extension of our grant to complete our goals.
- Will then seek further support to pursue full production.

Acknowledgments

- Ethan Balkin and DOE-UIN for funding this work.
- Scott Wilbur and his team at U of Washington for ongoing advice and for showing me their facility.
- Michael Zalutsky and his team at Duke University for the same, as well as for his review work on ^{211}At.